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TECHNICAL EVALUATION OF THE ACES DIGITAL WIDEBAND INTERCEPT SUBSYSTEM

by

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CAUTION

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ABSTRACT

This report documents the technical evaluation performed on the digital wideband intercept subsystem of the Advanced Communications ESM System (ACES). The evaluation consisted of a variety of laboratory measurements conducted primarily to characterize the sensitivity and dynamic range performance of the Steinbrecher digital tuner. However, these measurements also verified proper operation of the tuner controller, the fibre-optic interface, the spectral processor, and the PC interface.

RESUME

Ce rapport contient l'évaluation technique du sous-système d'interception numérique à large bande passante du 'Advanced Communications ESM System' (ACES). L'évaluation a consisté en diverses mesures en laboratoire pour caractériser principalement la sensibilité et la plage d'opération d'un syntonisateur numérique Steinbrecher. Ces mesures ont aussi servi à vérifier le bon fonctionnement du contrôleur du syntonisateur, de l'interface à fibre optique, de l'analyseur de spectre et de l'interface sur ordinateur personnel.

EXECUTIVE SUMMARY

For some time now, the military has fulfilled its requirement for tactical communications ESM in the HF and VHF radio bands through the use of scanning narrowband superheterodyne receivers. These receivers feature excellent dynamic range and selectivity but are relatively slow and not well suited for intercepting short duration signals.

In the last decade, speed has become a major concern as modern radios with burst and/or frequency agile modes have become increasingly popular on the battlefield. Hence, it is now necessary to develop faster intercept techniques that do not compromise the dynamic range and selectivity of the ESM system. To this end, the Electronic Support Measures Section is developing an Advanced Communications ESM System (ACES) using wideband receivers and digital signal processing to provide the necessary speed.

The most important component of this system is the digital wideband intercept subsystem; namely, the digital tuner and the spectral processor. Ultimately, these two items will determine overall the performance of the system in terms of sensitivity, dynamic range and speed. Therefore, to determine the performance limits of ACES, a technical evaluation was performed on the digital wideband intercept subsystem. The evaluation consisted of a variety of laboratory measurements conducted primarily to characterize the sensitivity and dynamic range performance of the digital tuner. However, these measurements also verified proper operation of the tuner controller, the fibre-optic interface, the spectral processor, and the PC interface.

The results of these measurements showed that the digital tuner has a noise figure of 14 dB and is only desensitized 5 dB by a +10 dBm out-of-band signal. The inband second and third order intercepts are +45 dBm and +6 dBm respectively, yielding a worst case two tone spurious free dynamic range of 85 dB. The out-of-band second and third order intercepts were measured to be +100 dBm and +45 dBm respectively. This level of performance is excellent and exceeds that of even the best narrowband surveillance receivers. Overall, the digital tuner is truly a high performance, high dynamic range receiver.

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1.0 INTRODUCTION

For some time now, the military has had a requirement to perform tactical communication ESM in the HF and VHF radio bands. This requirement presents a number of technological problems, the first of which is simply designing an intercept receiver system capable of monitoring the entire communication frequency and detecting every signal of interest (SOI). In the past, this signal acquisition problem has been solved to some extent through the use of scanning narrowband superheterodyne receivers. These receivers feature excellent dynamic range and selectivity but have never been able to satisfy the military's desire for speed.

In the last decade, this deficiency has become a major concern as modern radios with burst and/or frequency agile modes have become increasingly popular on the battlefield. The problem is that these new communication modes greatly reduce the time that any one frequency is used during a transmission and thus reduces the time available for the ESM system to intercept the frequency. Hence, it is now necessary to develop faster intercept techniques that do not compromise the dynamic range and selectivity of the ESM system.

To this end, the Electronic Support Measures Section is undertaking to develop an Advanced Communications ESM System (ACES) using wideband receivers and digital signal processing to provide the necessary speed. The instantaneous bandwidth of the receivers being used for ACES will be 2.1 MHz. Since this bandwidth will, in general, contain several SOIs, the receiver's intermediate frequency (IF) output will be digitized allowing the individual SOIs to be detected and identified with digital signal processing.

The most important components of any wideband digital intercept system are the digital tuner and the spectral processor. Ultimately, these two items determine the performance of the system in terms of sensitivity, dynamic range and speed.

The digital tuners used for ACES are Steinbrecher's state-of-the-art DT-14088 C-1 digital tuners. These receivers input signals contained in a tunable 2.1 MHz band, convert them to a 3.75 MHz IF and then digitize them with a high dynamic range, 14 bit A/D at a rate of 5 MHz (bandpass sampling). For further detail on the DT-14088 C-1, the reader is referred to [1].

The spectral processor chosen for ACES is the Regal A98113 Frequency Domain Processing Subsystem. The A98113 consists of two high speed fast Fourier transform (FFT) processors that are installed into the VME backplane of a Sun 4 workstation. Working together, these boards can perform FFTs up to 64K in size on data supplied through the VME bus or directly through external I/O ports on the boards. For more details on the capabilities of the A98113, the reader is referred to [2].

In order to determine the performance limits of ACES, noise figure and dynamic range tests were conducted on one of the digital tuners. These tests made use of a number of ACES subsystems including the tuner controller, the tuner, the fibre-optic interface, the spectral processor, and a PC interface[1]. As a result, the tests also verified proper end-to-end operation of these components. This report documents the procedures used and the results obtained while testing the digital receiver.

2.0 TEST PROCEDURES AND RESULTS

This section describes the ACES system configuration and the test procedures used to measure the noise figure and the dynamic range of the digital receiver. Note however, that characterizing the performance of a wideband receiver is not as straightforward as for a narrowband system. For wideband systems, it is necessary to test not only the out-of-band[2] performance of the RF components but also the in-band[3] performance of the IF components including, in this case, the A/D.

2.1 System Configuration

During these tests, ACES was configured as shown in Figure 1. Using the tuner controller, the receiver's input attenuation was set to 0 dB and the first LO was adjusted as required by each test. Test signals were then applied to the receiver's RF input and the fibre-optic, digital output was routed to the fibre-optic interface where it was converted to an electrical form compatible with the spectral processor. Finally, the spectral processor computed FFTs of the digital data and sent these to the PC interface where they were collected and analysed.

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[1]The PC interface is not actually a component of ACES proper. The interface was constructed to permit data collection for these tests and to validate the data produced by the digital receiver and the spectral processor during debugging of the connected system.

[2]Out-of-band performance refers to how the receiver reacts to signals which, for a given tuned centre frequency, fall outside the intended RF passband. Ideally, the tuner's RF and IF stages should filter out these signals before they affect the output.

[3]In-band performance refers to how the receiver reacts to signals which, for a given tuned centre frequency, fall within the intended RF passband. Ideally, the tuner's RF and IF stages should process these signals without introducing any extraneous signals.

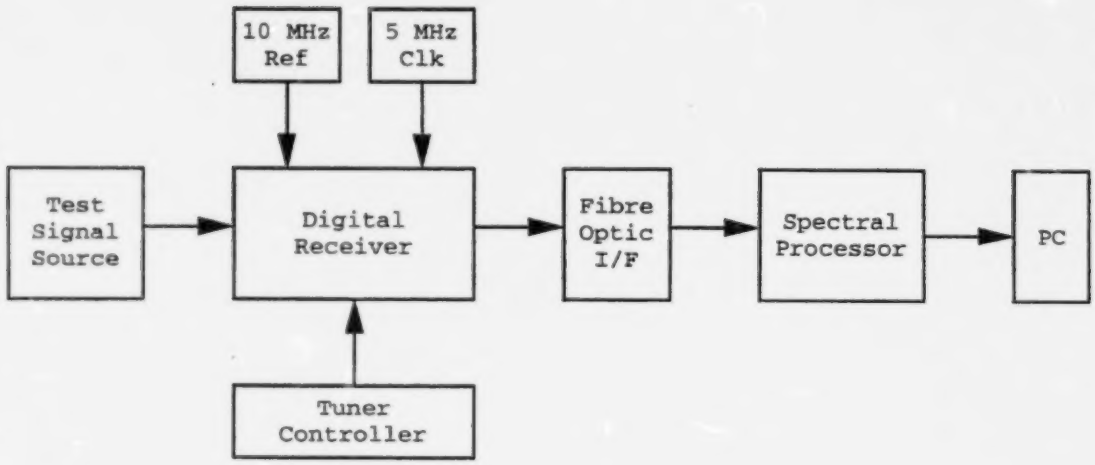

FIGURE 1: ACES CONFIGURATION

2.2 In-band Third Order Intercept

The receiver's in-band input third order intercept (TOI) was measured by applying two tones, 250 kHz apart, to the RF input; tuning the receiver such that both tones were within the RF passband; and then measuring the amplitudes of the $2f_1 \pm f_2$ and $2f_2 \pm f_1$ frequency components in the final FFT output. As per the receiver specifications, the amplitude of each tone was adjusted at the RF input to provide -7 dBFS[4] and the intermodulation products were measured using a 16K FFT with a minimum 4-point Blackman-Harris window.

Figure 2 shows the setup used to generate the test signals for measuring the receiver's in-band TOI. The two signal generators produced the test tones which were then added together with a hybrid adder and applied to the receiver. The two 30 dB attenuators connected between the signal generators and the adder served to increase the isolation between the signal generators and thereby decrease any third order products that may be generated by amplitude levelling circuits within the signal generators. Along with the final 15 dB attenuator, these attenuators also attenuated any signals picked up by the cables. Even then, it was also necessary to use semirigid coax between the adder and the receiver to prevent excessive pickup.

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[4]Zero dBFS is the signal amplitude at the RF input that would create a full scale (FS) signal at the tuner's A/D converter. For an attenuation setting of 0 dB, 0 dBFS is approximately -35 dBm.

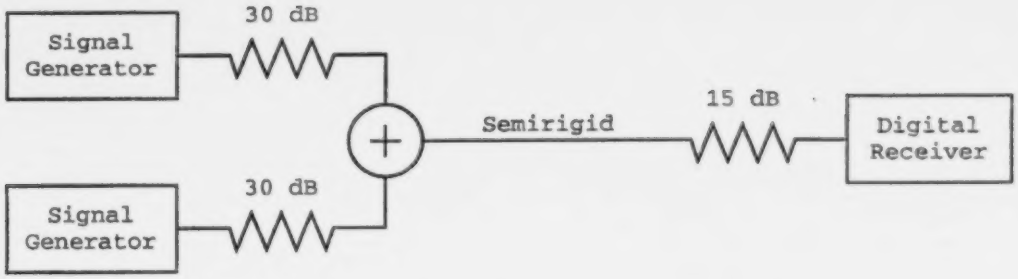

FIGURE 2: IN-BAND TWO TONE TOI TEST CONFIGURATION

TOI tests were conducted at several frequencies with the receiver always tuned to centre the test tones within the IF passband. As with most receivers, the dominant source of in-band intermodulation products should be the final IF circuits where the signal amplitudes are the greatest. Thus, the TOI measurements should be relatively consistent over frequency. Another set of tests were then performed in which the test tones were stepped across the IF passband. These tests were intended to identify any frequency dependencies within the receiver's IF circuits, and in particular, the A/D converter.

Tables 1 and 2 present the input parameters and the results for these two series of tests. According to the receiver specifications, no spurious signal should have an amplitude greater than -88 dBFS under these test conditions. As the tables show, the receiver tested easily meets this specification with spurious levels seldom exceeding -92 dBFS, and third order products seldom exceeding -94 dBFS, corresponding to an in-band third order intercept of about +3 dBm. Note that dashes (--) are used in the tables when the corresponding frequency component(s) were below the noise floor.

Figures 3 and 4 are plots of the periodograms, obtained by averaging 32 FFTs, for the third and second entries in Tables 1 and 2 respectively. These plots are representative of all the plots and show that the third order products were only a few dB stronger than the average noise floor which measured -97 dBFS. Since the measured third order terms were the sum of the third order product and the noise floor, the true amplitudes of the third order products were actually about 3 dB lower than measured, which would increase the TOI slightly. To verify this fact, the last test in Table 1 was repeated using 64K FFTs to increase the frequency resolution and thereby reduce the noise floor to less than -103 dBFS. The resulting periodogram is shown in Figure 5. As expected, the highest third order product of the -41.0 and -40.0 dBm inputs is only -99.7 dBFS, yielding an in-band TOI of +5.9 dBm.

TABLE 1: IN-BAND TWO TONE TOI TEST RESULTS (CENTRED)

Tuned Frq (MHz)	Input 1		Input 2		Max Spur (dBFS)	Max $2f_1 \pm f_2$ $2f_2 \pm f_1$ (dBFS)	TOI (dBm)
	Frq (MHz)	Pwr (dBm)	Frq (MHz)	Pwr (dBm)			
2.5	2.375	-41.9	2.625	-41.0	-92.0	-93.9	+2.0
12.5	12.375	-42.0	12.625	-41.1	-92.8	-94.8	+2.4
22.5	22.375	-41.5	22.625	-40.6	-93.3	-94.6	+2.8
32.5	32.375	-41.0	32.625	-40.1	-94.1	-94.8	+3.4
42.5	42.375	-40.8	42.625	-39.8	-93.2	-95.5	+4.0
52.5	52.375	-40.8	52.625	-39.8	-91.8	-94.8	+3.6
62.5	62.375	-40.9	62.625	-39.9	-93.0	-94.4	+3.3
72.5	72.375	-40.9	72.625	-39.8	-94.1	-94.5	+3.4
82.5	82.375	-40.6	82.625	-39.6	-93.5	-93.5	+3.2

TABLE 2: IN-BAND TWO TONE TOI TEST RESULTS (UNCENTRED)

Tuned Frq (MHz)	Input 1		Input 2		Max Spur (dBFS)	Max $2f_1 \pm f_2$ $2f_2 \pm f_1$ (dBFS)	TOI (dBm)
	Frq (MHz)	Pwr (dBm)	Frq (MHz)	Pwr (dBm)			
82.5	81.625	-40.5	81.875	-41.2	-92.5	-94.2	+2.7
82.5	81.875	-41.2	82.125	-41.5	-93.0	-94.1	+2.2
82.5	82.125	-41.3	82.375	-40.9	-93.5	-94.8	+2.8
82.5	82.625	-39.9	82.875	-40.1	-92.7	-95.1	+4.1
82.5	82.875	-40.2	83.125	-41.1	-93.1	-94.7	+3.2
82.5	83.125	-41.1	83.375	-41.0	-93.7	--	--

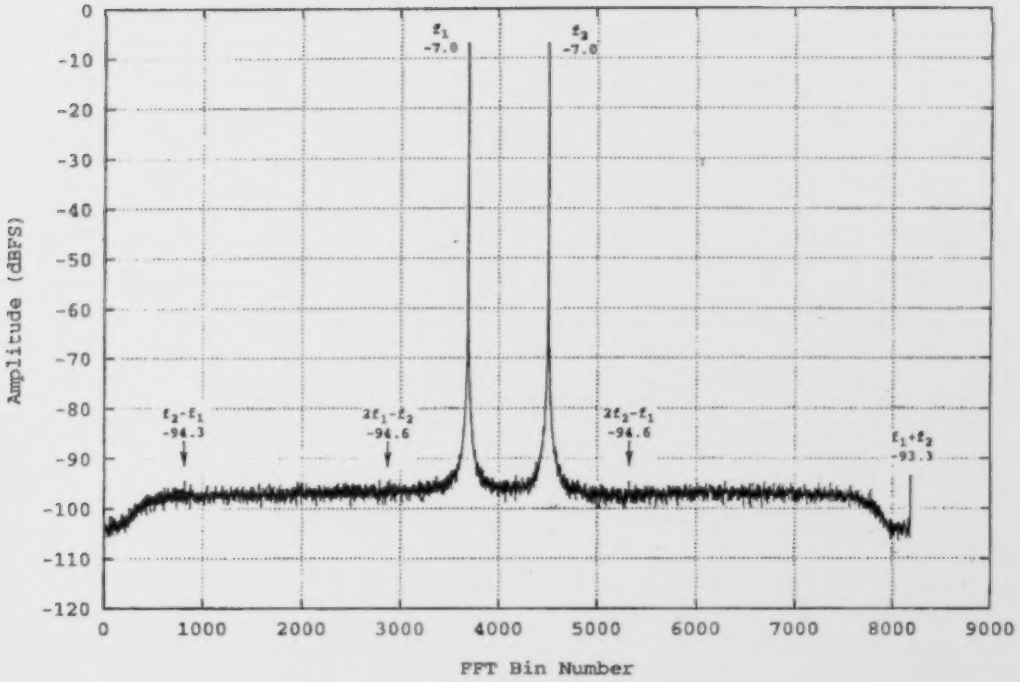

FIGURE 3: SAMPLE IN-BAND TWO TONE TOI PERIODOGRAM (CENTRED)

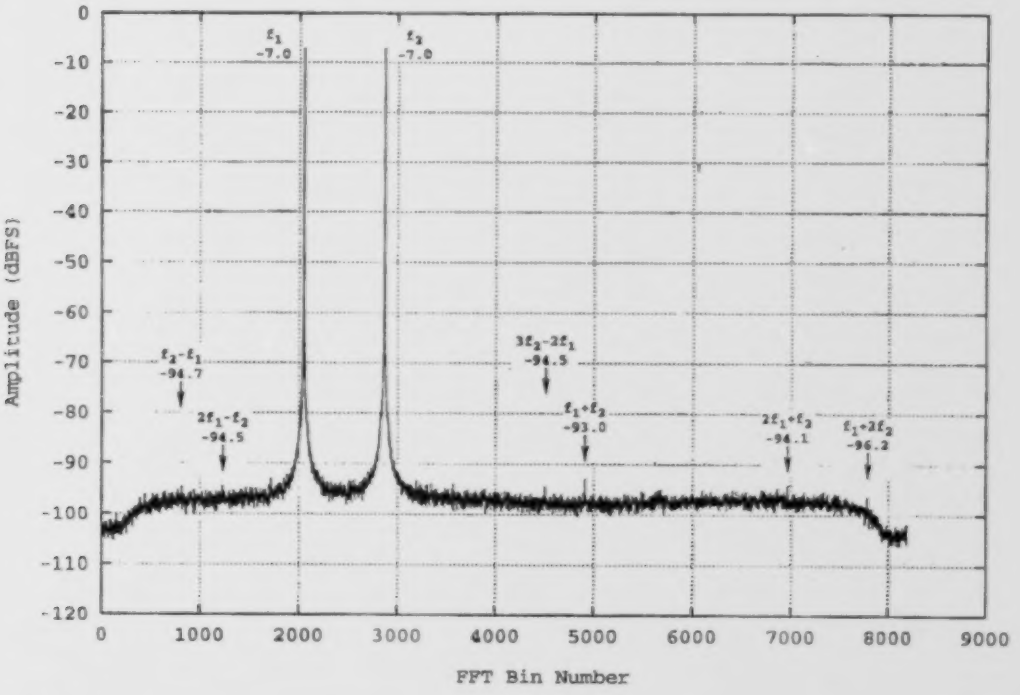

FIGURE 4: SAMPLE IN-BAND TWO TONE TOI PERIODOGRAM (UNCENTRED)

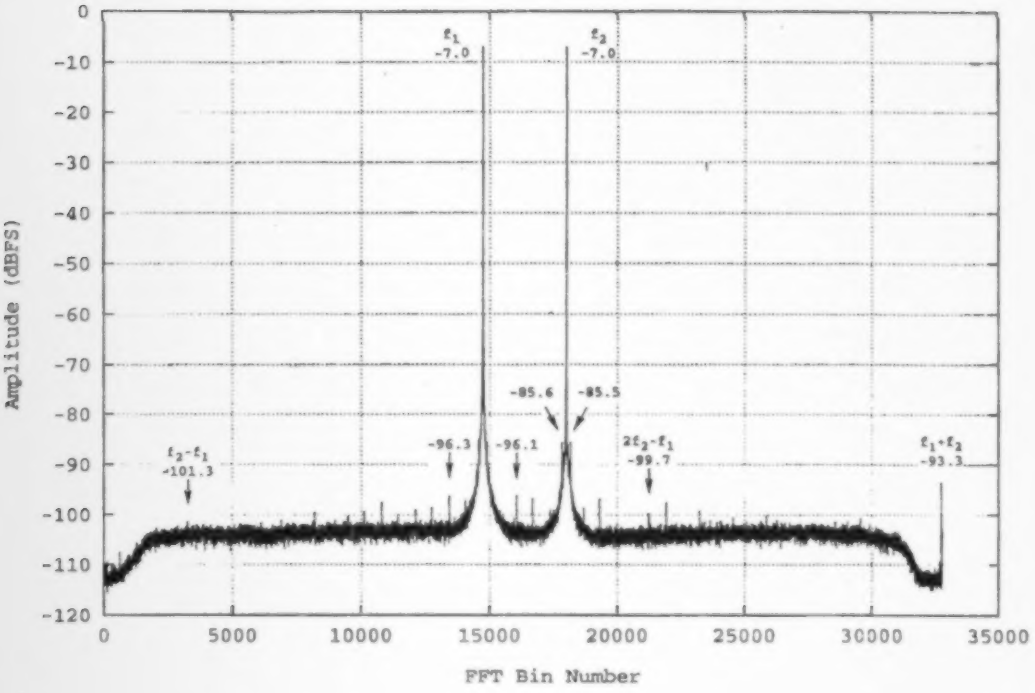

FIGURE 5: HIGHER RESOLUTION IN-BAND TWO TONE TOI PERIODOGRAM

Notice in Figure 5, though, that use of a low-noise signal source for the right most tone and a higher resolution FFT has also revealed close-in spurious side tones which slightly exceed the -88 dBFS specification. These side tones were subsequently investigated and were found to be a product of the 10 MHz external frequency reference supplied to the receiver. By changing the source of the frequency reference, these and most of the other spurious signals could be eliminated, with a different set of spurious signals replacing them. Thus, most of the spurious signals appear to be related to the external frequency reference. Unfortunately, a reference source satisfying the stringent requirements of the receiver was not available for testing.

The third order intercept was also measured using a single tone to test just the final IF circuits. Since these circuits are the primary source of in-band intermodulation products, the results should agree with those from the two tone tests. Figure 6 shows the setup used to generate the test signals for this test. The test tone was produced by the signal generator and a quartz filter ensured that the signal was free of harmonics. Semirigid coax and a 10 dB attenuator prevented excessive signal pickup.

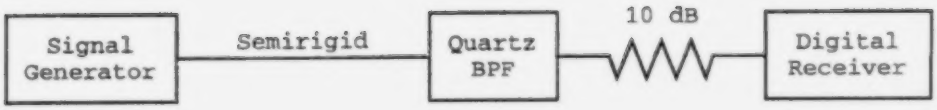

FIGURE 6: IN-BAND SINGLE TONE TEST CONFIGURATION

The results of this test are presented in Table 3 and the periodogram for the second entry is shown in Figure 7. According to theory, the single tone test should produce a TOI that is 4.75 dB better than the two tone test result; hence, the measured values are consistent with the previous results. As mentioned before, the spurious side tones surrounding the main peak in Figure 7 are due to the external frequency reference.

TABLE 3: IN-BAND SINGLE TONE TOI TEST RESULTS

Tuned Frq (MHz)	Input		Max Spur (dBFS)	$3f_1$ (dBFS)	TOI (dBm)
	Frq (MHz)	Pwr (dBm)			
21.4	21.400	-35.8	-90.3	--	--
22.4	21.400	-35.3	-90.8	-90.8	+9.6
21.6	21.400	-35.8	-88.9	-90.9	+9.2

2.3 In-band Second Order Intercept

The receiver's second order intercept (SOI) was measured concurrently with the third order intercept using the same signals and periodograms. Thus, the test setups shown in Figures 2 and 6 are also applicable to these tests.

Tables 4, 5 and 6 present the results for the different test procedures. Notice that, as in the third order tests, the single tone tests gave better results. Since theory predicts a 6 dB improvement, these measurements are consistent with the two tone results.

It should also be noted that these tests only measure the performance of the final IF circuits since the second order RF products do not fall within the tuned passband of the receiver. The results, however, are still significant since the IF circuits should be the dominant source of in-band intermodulation.

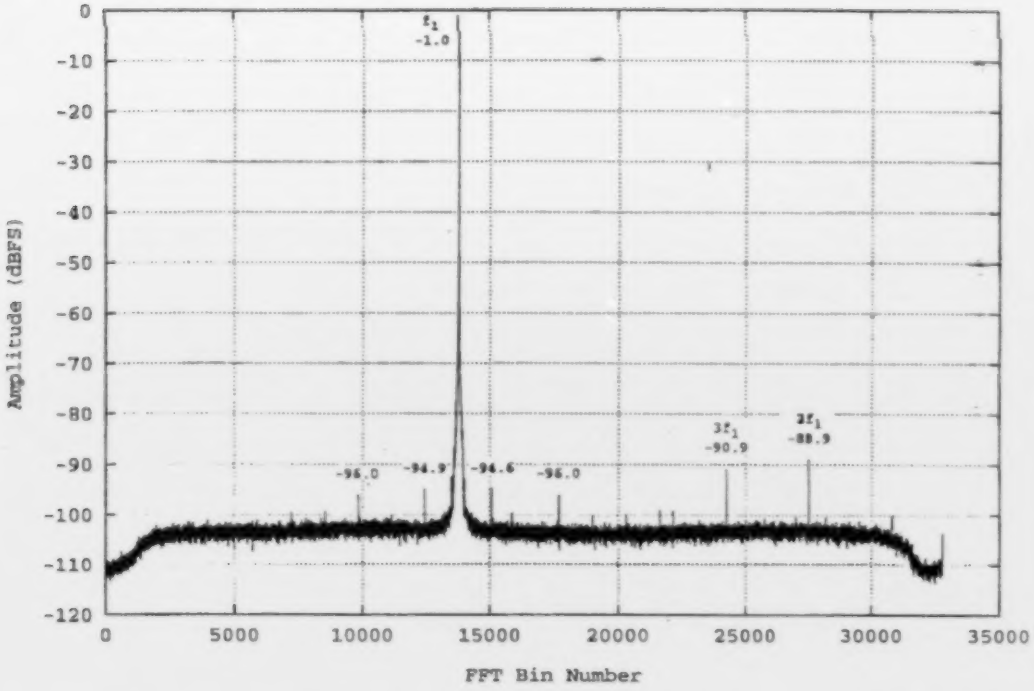

FIGURE 7: SAMPLE IN-BAND SINGLE TONE TOI PERIODOGRAM

TABLE 4: IN-BAND TWO TONE SOI TEST RESULTS (CENTRED)

Tuned Frq (MHz)	Input 1		Input 2		Max Spur (dBFS)	Max $f_2 \pm f_1$ (dBFS)	SOI (dBm)
	Frq (MHz)	Pwr (dBm)	Frq (MHz)	Pwr (dBm)			
2.5	2.375	-41.9	2.625	-41.0	-92.0	-92.0	+43.5
12.5	12.375	-42.0	12.625	-41.1	-92.8	-92.8	+44.2
22.5	22.375	-41.5	22.625	-40.6	-93.3	-93.3	+45.2
32.5	32.375	-41.0	32.625	-40.1	-94.1	-94.1	+46.5
42.5	42.375	-40.8	42.625	-39.8	-93.2	-93.2	+45.9
52.5	52.375	-40.8	52.625	-39.8	-91.8	-91.8	+44.5
62.5	62.375	-40.9	62.625	-39.9	-93.0	-93.0	+45.6
72.5	72.375	-40.9	72.625	-39.8	-94.1	-94.1	+46.7
82.5	82.375	-40.6	82.625	-39.6	-93.5	-94.0	+46.9

TABLE 5: IN-BAND TWO TONE SOI TEST RESULTS (UNCENTRED)

Tuned Frq (MHz)	Input 1		Input 2		Max Spur (dBFS)	Max $f_2 \pm f_1$ (dBFS)	SOI (dBm)
	Frq (MHz)	Pwr (dBm)	Frq (MHz)	Pwr (dBm)			
82.5	81.625	-40.5	81.875	-41.2	-92.5	-92.5	+44.6
82.5	81.875	-41.2	82.125	-41.5	-93.0	-93.0	+44.6
82.5	82.125	-41.3	82.375	-40.9	-93.5	-93.5	+45.4
82.5	82.625	-39.9	82.875	-40.1	-92.7	-92.7	+45.7
82.5	82.875	-40.2	83.125	-41.1	-93.1	-93.1	+45.4
82.5	83.125	-41.1	83.375	-41.0	-93.7	-93.7	+45.6

TABLE 6: IN-BAND SINGLE TONE SOI TEST RESULTS

Tuned Frq (MHz)	Input		Max Spur (dBFS)	$2f_1$ (dBFS)	SOI (dBm)
	Frq (MHz)	Pwr (dBm)			
21.4	21.400	-35.8	-90.3	-90.3	+53.5
22.4	21.400	-35.3	-90.8	-91.9	+55.6
21.6	21.400	-35.8	-88.9	-88.9	+52.1

2.4 Out-of-Band Third Order Intercept

The receiver's out-of-band third order intercept was measured using both the single tone and two tone tests. Given that the test tones are out-of-band by definition, both of these tests only measure the performance of the RF circuits.

For the two tone tests, two tones separated by 1 MHz were applied to the RF input. The receiver was then tuned such that the nearest tone was 2 MHz from the centre frequency. Finally, the $2f_1-f_2$ and $2f_2-f_1$ frequency components were measured using 64K FFTs. As per the receiver specifications, the amplitude of each tone was adjusted to be 0 dBm at the RF input.

Figure 8 shows the setup used to generate the test signals for measuring the receiver's out-of-band TOI via the two tone test. The two signal generators produced the test tones which were then added together with a hybrid adder and applied to the receiver. The two amplifiers connected between the signal generators and the adder boosted the signal power to the required levels while

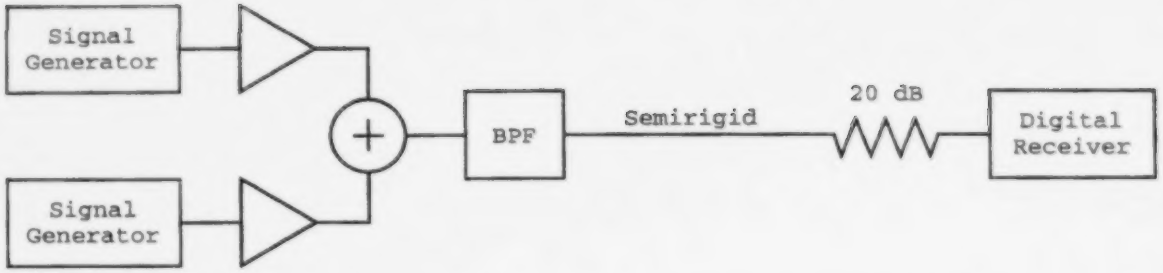

FIGURE 8: OUT-OF-BAND TWO TONE TOI TEST CONFIGURATION

providing additional isolation between the signal generators. A bandpass filter then ensured that the test signals were free of any intermodulation products that may be generated by the adder or the signal generators. Finally, semirigid coax and a 20 dB attenuator were used to prevent excessive signal pickup in the cables.

The single tone test was performed by applying one tone to the RF input, tuning the receiver to the tone's third harmonic and then observing the amplitude of the harmonic in the final FFT output. Figure 9 shows the setup used to generate the input signal for the single tone test. The test tone was produced by the signal generator and then amplified to the required level. A quartz filter ensured that the signal was free of harmonics, noise and other spurious with semirigid coax and a 10 dB attenuator preventing excessive signal pickup.

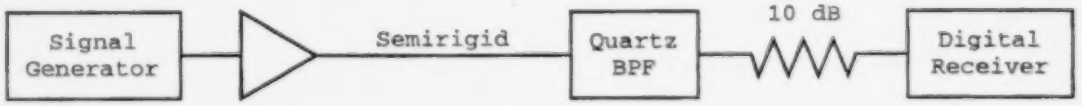

FIGURE 9: OUT-OF-BAND SINGLE TONE TOI TEST CONFIGURATION

Table 7 shows the input signal parameters and the results for these tests. The two tone tests yielded TOIs of +45.8 dBm and +50.5 dBm, surpassing the receiver specification of +38 dBm by a healthy margin. The single tone test, which should produce a TOI that is 4.75 dB better than the two tone result, produced a TOI of +52.0 dBm. Another result of the two tone tests is that they also produced fifth order products ($3f_1-2f_2$ and $3f_2-2f_1$) allowing the fifth order intercept to be measured. This intercept is not specified for the receiver but was measured to be +31.7 dBm.

TABLE 7: OUT-OF-BAND TOI TEST RESULTS

Tuned Frq (MHz)	Input 1		Input 2		Third Order Term (dBFS)	TOI (dBm)
	Frq (MHz)	Pwr (dBm)	Frq (MHz)	Pwr (dBm)		
62.5	59.500	0.0	60.500	0.0	-58.1	+45.8
57.5	59.500	0.0	60.500	0.0	-67.6	+50.5
64.2	21.400	0.0	--	--	-70.5	+52.0

Figures 10 and 11 show the periodograms resulting from the two tone tests, ie. the first two entries of Table 7. For the most part, Figure 10 is as expected, showing the third and fifth order products and only one other small spurious signal which was not identified, but which is likely attributable to the external reference signal. Figure 11, on the other hand, contains a couple of extra spurious signals which cannot be blamed on the external reference. The strongest of these, measuring -70.5 dBFS, is the second harmonic of the second IF signal corresponding to the 59.5 MHz input tone. Ideally, the 59.5 MHz signal should be removed by the first IF filter. However, since the signal is close to the first IF passband, some of it gets through. Based on the resulting spurious signal, the out-of-band second order intercept of the second IF circuits is +104 dBm. The other spurious signal, measuring -92.7 dB, is a third order product produced within the second IF section of the receiver. Specifically, it is twice the IF frequency of the 59.5 MHz signal plus the IF frequency of the 60.5 MHz signal. The corresponding out-of-band third order intercept for the second IF circuits is thus +63 dBm.

Admittedly, the concept of out-of-band intermodulation for an IF circuit is somewhat unusual given that most IF signals are assumed to be and usually are in-band. In this case, however, what should be out-of-band signals are leaking into the IF band and creating intermodulation products. Thus the only real difference between the in-band and out-of-band intermodulation products is that the out-of-band signals are attenuated by the first IF filter before they generate spurious products. These spurious signals are therefore much weaker than those produced by true in-band signals.

Figure 12 shows the periodogram from the single tone test. Other than the third harmonic of the input tone, the spectrum does not contain any significant signals.

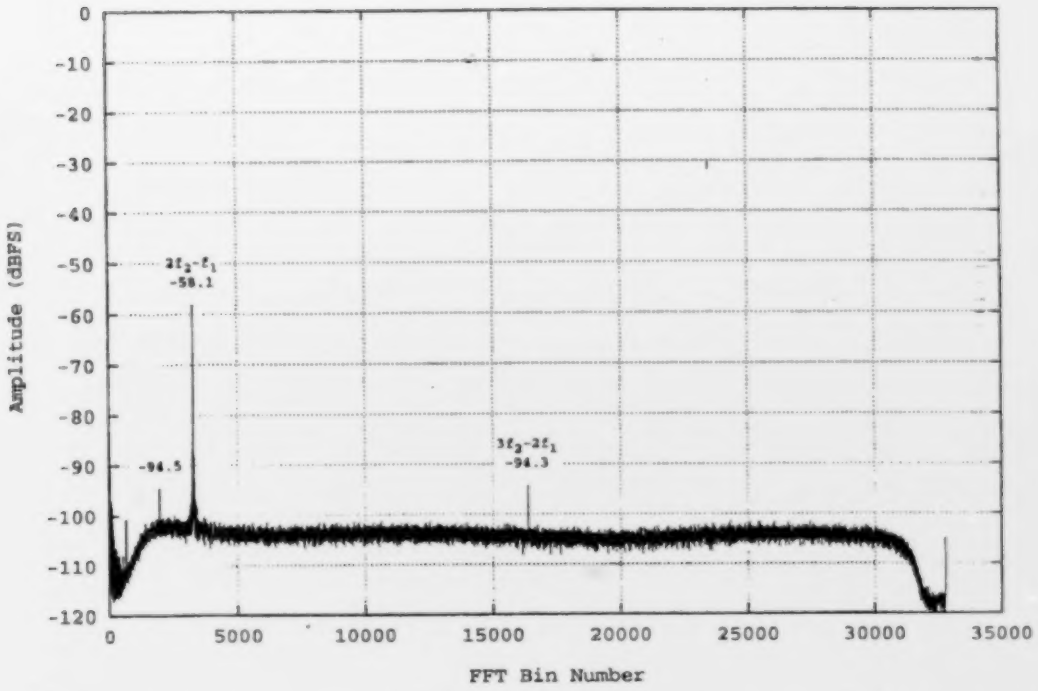

FIGURE 10: OUT-OF-BAND TWO TONE TOI PERIODOGRAM (TEST 1)

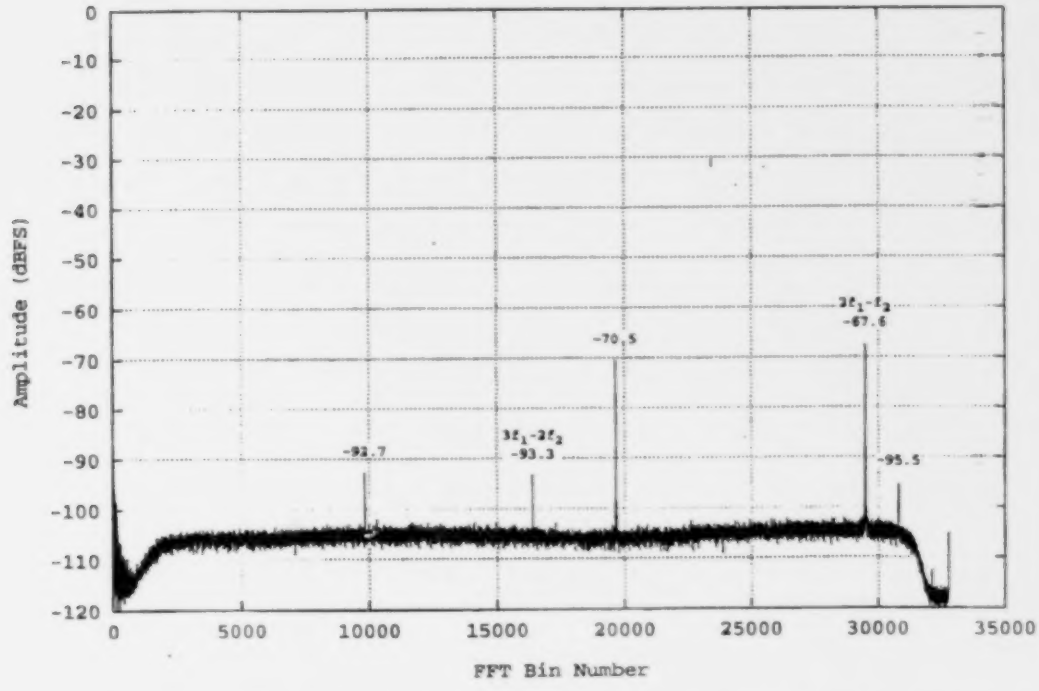

FIGURE 11: OUT-OF-BAND TWO TONE TOI PERIODOGRAM (TEST 2)

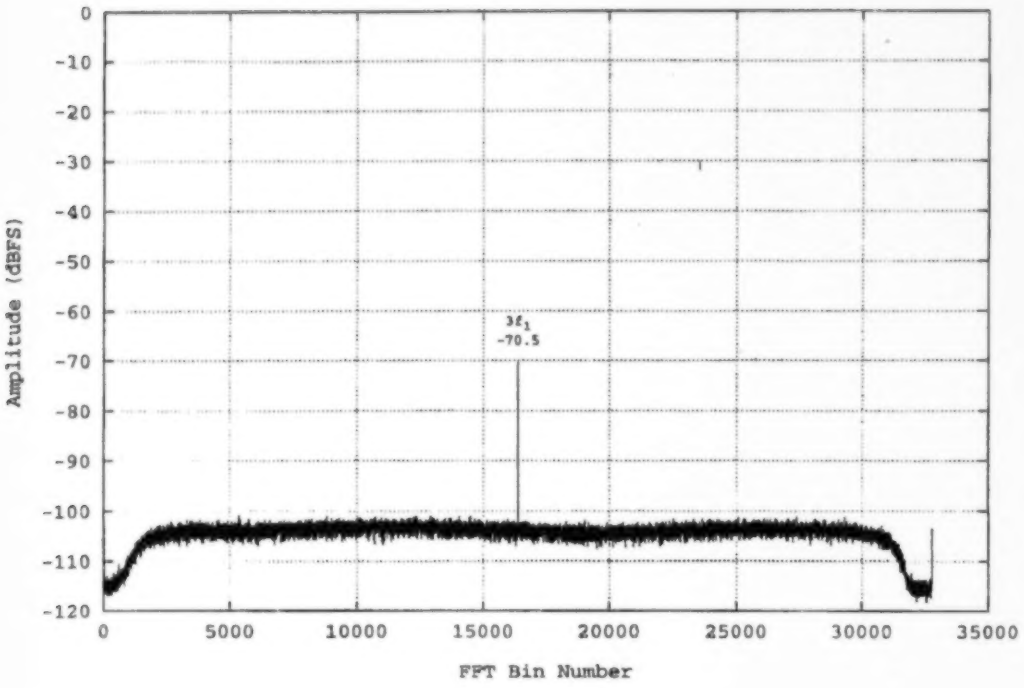

FIGURE 12: OUT-OF-BAND SINGLE TONE TOI PERIODOGRAM

2.5 Out-of-Band Second Order Intercept

The out-of-band second order intercept was measured using the same procedure, the same input signals and, hence, the same test setup as the out-of-band single tone third order intercept test (see Figure 9). The only difference was that the receiver was tuned to the second harmonic of the input signal instead of the third. As with the other out-of-band tests, these tests isolate the performance of the RF circuits.

The resulting periodogram (Figure 13) clearly shows the second order product at an amplitude of -67.2 dBFS corresponding to a second order intercept of +100.5 dBm. This result far exceeds the receiver specification of +76 dBm.

2.6 Noise Figure

The receiver's noise figure was measured under various conditions ranging from no input signal to a +10 dBm out-of-band signal. The test setup used was identical to that used to measure the out-of-band single tone intermodulation products (see Figure 9). Only the amplitude of the input signal and the centre frequency of the receiver were varied. The input parameters and

the results can be found in Table 8. Not counting the last entry in the table, the receiver's noise figure is about 14 dB which meets the 15 dB specification.

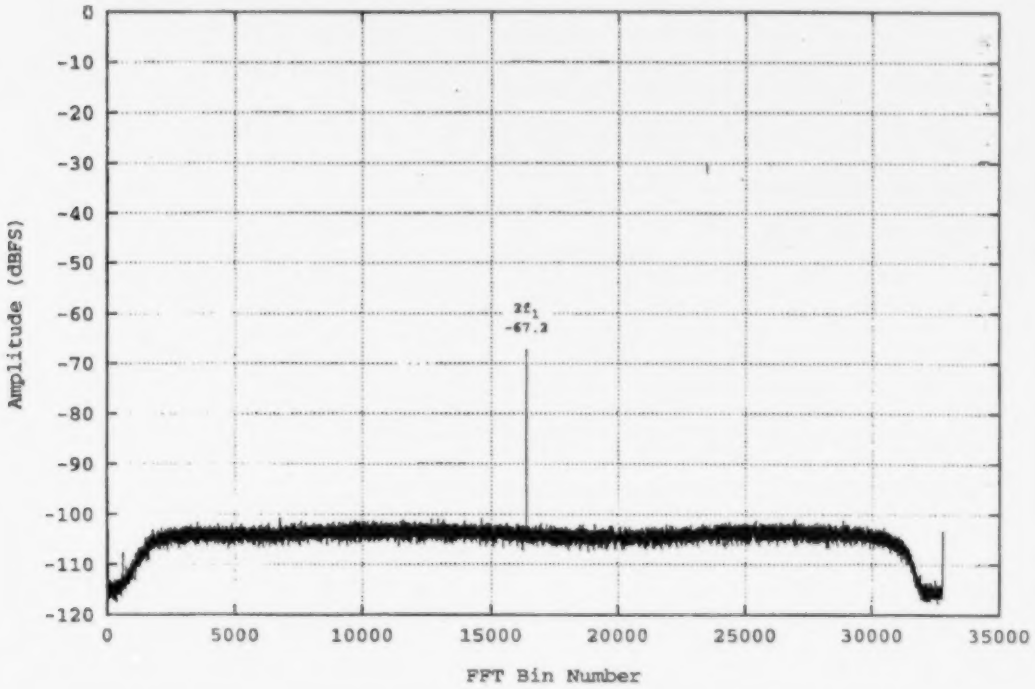

FIGURE 13: OUT-OF-BAND SINGLE TONE SOI PERIODOGRAM

TABLE 8: NOISE FIGURE TEST RESULTS

Tuned Frq (MHz)	Input		Avg Noise Floor (dBFS)	NF (dB)
	Frq (MHz)	Pwr (dBm)		
21.4	21.400	-35.8	-103.4	14.0
22.4	21.400	-35.3	-103.2	14.6
21.4	--	--	-103.9	13.8
21.4	21.400	-54.4	-104.0	13.8
21.6	21.400	-35.8	-103.3	14.1
24.4	--	--	-104.0	14.1
24.4	21.400	-80.0	-103.4	14.7
24.4	21.400	+10.0	-99.3	18.8

Figure 14 shows the periodogram for the first entry in Table 8. The average noise floor corresponds to a noise bandwidth of 153 Hz and measures -103.4 dBFS, equivalent to -138.2 dBm at the receiver's RF input. Thermal noise measured with the same noise bandwidth would be -152.2 dBm.

The last entry in the table is a special case designed to measure the effect of a very strong out-of-band signal on the noise figure, a specification known as desensitization or reciprocal mixing. Basically, this specification is a measure of the phase noise on the LOs which ultimately determines the noise limited dynamic range of the system. As Table 8 shows, a +10 dBm signal 3 MHz from the tuned centre frequency only raises the noise figure by about 5 dB.

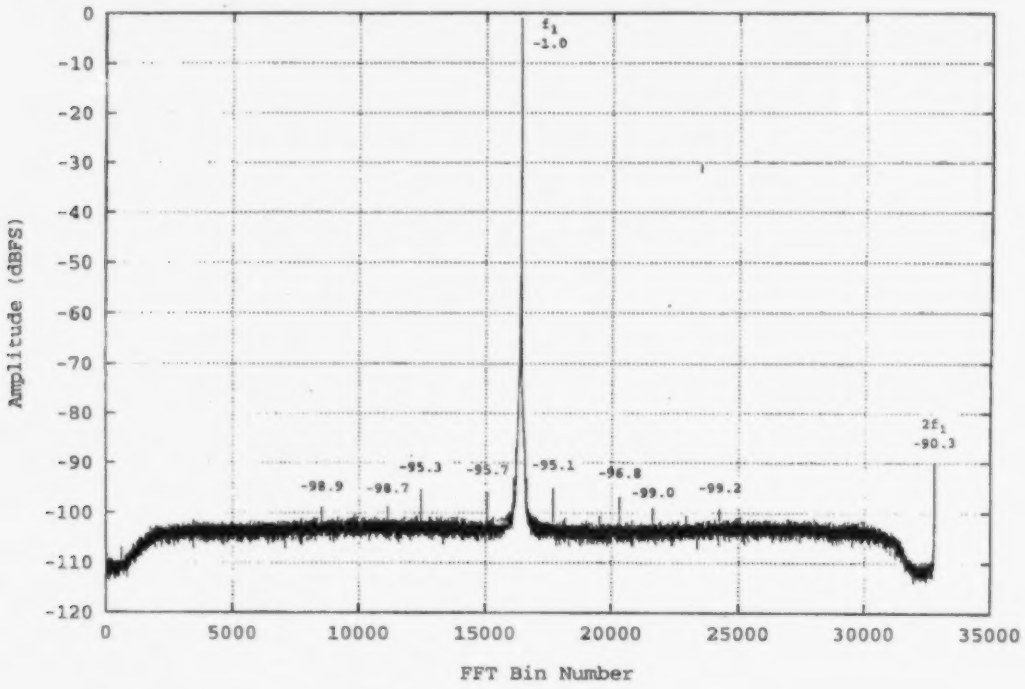

FIGURE 14: SAMPLE NOISE FIGURE TEST PERIODOGRAM

3.0 CONCLUSIONS

The Steinbrecher DT-14088 C-1 is truly a high performance, high dynamic range receiver. Its noise figure was measured to be about 14 dB. While this figure is not spectacular, it does agree well with the specification of 15 dB. Furthermore, the noise figure is largely unaffected by strong out-of-band signals in that a +10 dBm signal (45 dB above the maximum in-band signal) only raises the noise figure by 5 dB.

The in-band input third order intercept point of the receiver was found to be about +6 dBm, a value which is typical of out-of-band intercepts for narrowband receivers. Similarly, the in-band second order intercept was measured at roughly +45 dBm. In terms of the FFT output, a single -1 dBFS signal never produced a second order product above -89 dBFS or a third order product above -90 dBFS. Likewise, two -7 dBFS signals never produced a second order product above -92 dBFS or a third order product above -94 dBFS. These values meet the receiver specification of -88 dBFS and yield a worst case two tone spurious free dynamic range of 85 dB.

The receiver's out-of-band, second and third order intercepts were measured to be roughly +100 dBm (single tone test) and +45 dBm respectively, surpassing the specifications of +76 dBm and +38 dBm. This level of performance is excellent and exceeds that of even the best narrowband surveillance receivers. Also, the out-of-band fifth order intercept, which is not specified, was measured to be +31 dBm.

Two other important parameters that were discovered during testing are the out-of-band, second and third order intercepts of the final IF circuits. It was found that a signal 2 MHz higher than the tuned centre frequency produces a final IF signal whose second harmonic falls within the IF passband. The out-of-band second order intercept of the final IF was thereby found to be about +104 dBm. Similarly, when another signal 3 MHz above the tuned centre frequency is added to the first, one of the IF third order products falls within the passband. By measuring this product, the out-of-band third order intercept of the final IF was found to be +63 dBm. Note that both of these figures are better than the corresponding overall second and third order intercepts and thus are not a major concern.

Except for the intermodulation products, all the observed spurious signals appeared to be due to a substandard external reference source and/or digitizing clock. Notwithstanding this fact, all the spurious signals except for a couple of close-in side tones still met the specification of -88 dBFS. In short, the spurious (and close-in noise) performance of the receiver appears to be governed solely by the spectral purity of the LOs and the sampling clock, which in turn hinges on the purity of the external signals supplied to the receiver.

4.0 REFERENCES

[1] Steinbrecher Corporation, "User Manual - RF Receiver Unit - Steinbrecher Model DT-14088 C-1 Digital Tuner", Burlington, Massachusetts.

[2] Defence Science & Technology Organization, "A98113 Frequency Domain Processing Subsystem", DSTO Data Sheet #DSTO 24, Austek Microsystems Pty. Ltd., Salisbury, Australia, 1989.

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